ABSTRACT
Recent developments in computer design software for airfield pavement design, have simplified the design process to a great extent. The Federal Aviation Administration’s Rigid and Flexible Iterative Elastic Layered Design software (FAARFIELD) is one of their newly released design programs. FAARFIELD is based on AC 150/5320-6E, which includes Finite Elemental Modeling approaches. For flexible pavement design, FAARFIELD uses the similar structural response and failure models as LEDFAA 1.3. For rigid and overlay pavement design, FAARFIELD combines a three-dimensional finite element analysis with a performance/failure model based on full scale test result from National Airport Pavement Test Facility (NAPTF) and re-analysis of USACE full scale test results. With the application of appropriate calibration factors, FAARFIELD is considered one of the most effective tools in simulating and material modeling. FAARFIELD is also capable of handling New Large Aircrafts (NLA) with complex landing gear configuration including B-777, Airbus A380 and An-225. Other recent developments in pavement management software includes COMFAA 3.0 (as per AC150/5335-5B) and FAAPA VEAIR (Beta Version, expected to release soon). The objective of this paper is to introduce Airport Engineering, some of the innovative pavement technologies in computer design software-Finite Elemental Modeling, Pavement Management Technologies and various Decision making criteria “Decision Matrix” that have been using at Houston Airport Systems for several years. Pavement strength evaluation techniques and reporting criteria based on ACN-PCN evaluation using recent updated version of COMFAA 3.0, and application of NDT for sub-grade modulus evaluation and their implication on ACN-PCN determination are also presented and discussed. Finally, the outcomes of preliminary investigation on “Evaluation of Corrosion Potential of Native Sub-grade Soils though Soils Resistivity Analysis at Houston Airports Systems” are also presented.

Key Words: Soil, Pavement Design, FAARFIELD, COMFAA, ACN/PCN, NDT, Corrosion, Resistivity
Airport Engineering

Overview

1. Introduction to Houston Airport Systems
2. Introduction to Pavement Design and Design Software
3. Pavement Management System
4. Soils Resistivity and Corrosion Potential of Native Sub-grade Soils at Houston Airport Systems
Section-1: Introduction

- Houston Airport System
- General Airport Features
- Instrumentation Landing Systems
LOCATION MAP: HOUSTON AIRPORT SYSTEMS

George Bush Intercontinental Airport
William P. Hobby Airport
Ellington Airport
5 Major Runways
8L/26R = 9,000’
15L/33R = 12,000’
8R/26L = 9,400’
9L/27 = 10,000’
15R/33L = 10,000’
William P. Hobby Airport
Ellington Airport
Ellington Airport

This Airport is Currently Operated by Military, NASA, and General Aviation
General Airport Features

- Terminal Buildings/Control Tower
- Runways/Taxiways
- Instrumentation Landing System
- Jet Bridge/ Gates
- Fuel Tank/Pipelines
- Strom Water Management/Sewer Systems
- Detention Pond/ Lift Stations
- Air quality/Noise/Hazardous Material
- Wetland/Biotic Communities
Instrumentation Landing System

Glide Slope & Antenna

Corrects the Descent Path in V. Direction

- Located Between 750’-1250’ From the Approach end of Runway
- Transmits a Glide Path Beam at 1.4 Degree Wide
- Path Projection of 3 Degree
Instrumentation Landing System

- Transmits Signals To The Pilot
- Provide Lateral Guidance
- Aligns Horizontal Position with Runways

Localizer & Marker
Navigational Aids & Other FAA-Operated Facilities

- Airport Surveillance Radar
- Navigational Aids And Lighting Systems
- Doppler Radar- Enhance Weather Prediction
- Low level Wind Shear System
- Aircraft Rescue And Firefighting Facility

Ground Based Augmentation System to Global Positioning System (GPS) provides a very precise navigation service (low visibility conditions)
FAA Instrument Landing System
STANDARD CHARACTERISTICS AND TERMINOLOGY

ILS approach charts should be consulted to obtain variations of individual systems.

**VHF LOCALIZER**
- **FUNCTION:** Provides Horizontal Guidance.
- **LOCATION:** At Decision Height Point, (H) ± 000 Ft Longitudinal + ± 200 Ft Lateral.
- **FREQUENCY:** 75 MHz.
- **MODULATION:** 1300 Hz, 85%.
- **KEYING:** Alternate dot and dash.

**MIDDLE MARKER**
- **FUNCTION:** Indicates Decision Height Point.
- **LOCATION:** At Decision Height Point, (H) ± 000 Ft Longitudinal + ± 200 Ft Lateral.
- **FREQUENCY:** 75 MHz.
- **MODULATION:** 1300 Hz, 85%.
- **KEYING:** Alternate dot and dash.

**DMF Glide Slope**
- **FUNCTION:** Provides Vertical Guidance to Final Approach Path.
- **LOCATION:** Directly below point (H) where Glide Slope intersects the minimum holding altitude, ± 000 Ft Longitudinal & Lateral.
- **FREQUENCY:** 329.3 to 335.0 MHz.
- **MODULATION:** Navigation Modulation on path 40% (each) for 0 Hz, and for 100 Hz.
- **PATH:** Established at an angle between 2 1/2 and 3 degrees.
- **PATH WIDTH:** Path Width (W) approximately 1.4 (Full Scale Limits).

**FREQUENCY:** 75 MHz.
- **MODULATION:** 400 Hz, 95%.
- **KEYING:** Two dashes/second.

**OUTER MARKER**
- **FUNCTION:** Indicates Glide Slope Intercept Point.
- **LOCATION:** Directly below point (H) where Glide Slope intersects the minimum holding altitude, ± 000 Ft Longitudinal & Lateral.
- **FREQUENCY:** 75 MHz.
- **MODULATION:** 400 Hz, 95%.
- **KEYING:** Two dashes/second.

*NOTE:* Composite locators, rated 26 watts output, installation at mid point of markers and some middle markers. A 1520 Hz tone, modulating the carrier about 55%, is keyed with the first letter of the ILS identification on the outer locater and the last two letters on the middle locator. At some locations, simultaneous voice transmissions from the control tower are provided, with appropriate reduction in identification percentage.
Section-2

Pavement Design and Design Software
Design Components

Design Components - Pavement design
**Fundamental of Pavement Design**

**Pavement Types**

**Rigid PCC**
- Jointed Plain Concrete Pavement (JPCP/JCP)
- Jointed Reinforced Concrete Pavement (JRCP)
- Continuously Reinforced Concrete Pavement (CRCP)
- Pre-stressed Concrete Pavement (PCP)

**Flexible ACP/HMA**
- Full Depth
- Layered
  - Granular
  - Bound layers
- Surface Treatment
- Composite
Fundamental of Pavement Design

Pavement Components

**Rigid Pavement**
Portland Cement Concrete Slab
Base
Sub-grade

**Flexible Pavement** (Layered System)
Asphaltic Wearing Surface
Base
Sub-base
Sub-grade
Fundamental of Pavement Design

Factors Affecting Pavement Design

Types of Aircraft
- Loads
  - Anticipated frequency
- Gear configuration

Type of facility considered
- Runway
- Taxiway
- Apron
- Hangar Floor

Supporting value of the sub-grade
Characteristics of available construction Material
Fundamental of Pavement Design

Wheel Loading

Pavement Thickness
Pavement Stiffness
**Environmental Loading** – Temperature and Moisture
Joint Spacing
Reinforcement
HMA Stiffness
Fundamental of Pavement Design

Fundamental Design Concepts

Application
Load and Environment
Principle of Superposition
Stress Dependent On:
  Gear Spacing
  Magnitude and tire pressure
  Number of wheels

Fatigue
Layered Concept
Flexible Pavement Design

Must also guard against potential failure in base layers

Approximate Line of Wheel-Load Distribution

Horizontal Strain and Stress at the bottom of the asphalt

Vertical Subgrade Strain
Flexible Pavement Layer Parameters- LED vs. CBR

**Layered Elastic Method**

**Surface**
- $E_S$, $\mu_S$, $h$

**Base**
- $E_B$, $\mu_B$, $h_B$

**Subbase**
- $E_{SB}$, $\mu_{SB}$, $h_{SB}$

**Subgrade**
- $E_{SG}$, $\mu_{SG}$, $h_{SG}$

**Wheel Load**

**Subgrade Support**

**CBR Method**
- Not Defined
- CBR
- CBR
- CBR

$E = $ Elastic Modulus
$h = $ thickness
$\mu = $ Poisson’s Ratio

CBR = California Bearing Ratio
- **Flexible Pavement Design Based on Layered Elastic Design Procedure**
  - US Corp of Engineers CBR Method - no longer used.

- **Rigid Pavement Design Based on 3-Dimensional Finite Element Model**
  - Westergaard design procedure no longer used.
Traffic Models

- New procedures require that ALL anticipated traffic be included in the traffic model.
- Concept of “Design Aircraft” is no longer used.
- Cumulative Damage Factor (CDF) replaces need for design aircraft procedure.
HISTORICAL DESIGN PROSPECTIVE

CBR METHOD: Flexible Pavement

Westergaard’s Approach-(Rigid Pavement)
EQUIVALENT TRAFFIC METHOD (FAA, 1975)

Determination of annual aircraft departure by each aircraft and convert them into equivalent annual departure in terms of landing gear configuration

<table>
<thead>
<tr>
<th>To Convert From</th>
<th>To</th>
<th>Multiply Departures By</th>
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</thead>
<tbody>
<tr>
<td>Single wheel</td>
<td>Dual wheel</td>
<td>0.8</td>
</tr>
<tr>
<td>Single wheel</td>
<td>Dual tandem</td>
<td>0.5</td>
</tr>
<tr>
<td>Dual wheel</td>
<td>Dual tandem</td>
<td>0.6</td>
</tr>
<tr>
<td>Double dual tandem</td>
<td>Dual tandem</td>
<td>1.0</td>
</tr>
<tr>
<td>Dual tandem</td>
<td>Single wheel</td>
<td>2.0</td>
</tr>
<tr>
<td>Dual tandem</td>
<td>Dual wheel</td>
<td>1.7</td>
</tr>
<tr>
<td>Dual wheel</td>
<td>Single wheel</td>
<td>1.3</td>
</tr>
<tr>
<td>Double dual tandem</td>
<td>Dual wheel</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Factors for Converting Annual Departures by Aircraft to Equivalent Annual Departures by Design Aircraft

\[
\log R_1 = \log R_2 \times \left(\frac{W_2}{W_1}\right)^{1/2}
\]

where \( R_1 \) = equivalent annual departures by the design aircraft

\( R_2 \) = annual number of departures by an aircraft in terms of design aircraft landing gear configuration

\( W_2 \) = wheel load of the design aircraft

\( W_1 \) = wheel load of the aircraft being converted
RUNWAY LENGTH DETERMINATION

FACTORS: ELEVATION, TEMPERATURE, PRESSURE AND MTOW
## Selection of Pavement Material and Specification

<table>
<thead>
<tr>
<th>Surface</th>
<th>BASE</th>
<th>SUBBASE</th>
<th>SUBGRADE</th>
</tr>
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<tbody>
<tr>
<td>P-401</td>
<td>P-209</td>
<td>P-154</td>
<td>P-152</td>
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<td>P-403</td>
<td>P-208</td>
<td>P-210</td>
<td>P-155*</td>
</tr>
<tr>
<td>P-501</td>
<td>P-211</td>
<td>P-212</td>
<td>P-157*</td>
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<tr>
<td></td>
<td>P-304*</td>
<td>P-213</td>
<td>P-157*</td>
</tr>
<tr>
<td></td>
<td>P-306*</td>
<td></td>
<td>P-158*</td>
</tr>
<tr>
<td></td>
<td>P-401*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P-403*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubblized PCC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Chemically Stabilized Materials
FEM Model Approach
Rigid Pavement

Critical Load Condition Assumptions

- Maximum stress at pavement edge
- 75% load transfer to adjacent slab
DEVELOPMENT OF PAVEMENT DESIGN SOFTWARE

LEDFAA 1995

AC 150/5320-6D

COMFAA

FEAFAA

FAARFIELD 2009
Gear Configuration & Naming Convention - Complex Aircraft

- **AN-125**
- **AN 225**
- **3D**
- **B 777**

**Configurations:**
- Single (S)
- Dual (D)
- Triple (T)
- Quadruple (Q)

**Examples:**
- 2 Singles in Tandem (2S)
- 2 Singles in Tandem (2D)
- 2 Triples in Tandem, 2 Quadruples in Tandem (2T)
- 3 Singles in Tandem (3S)
- 3 Triples in Tandem (3T)
- 3 Quadruples in Tandem (3Q)

**Additional Notes:**
- B747
- A380
- Lockheed C5
INTRODUCTION-TO  FINITE ELEMENTAL MODELING-  FAARFIELD

Based on - Layered Elastic and 3D-FE modeling
AC 150/5320-6E (Current)

Computer Programs:

• LEAF (layered elastic analysis)
  Visual Basic 2005
• NIKE3D (3D finite element analysis)-
  FORTRAN
• INGRID (3D mesh generation)
INTRODUCTION-TO
FINITE ELEMENTAL MODELING
FEM Model Approach

Curling Stress

3D-FEM Rigid Pavement Mesh Displayed Using NikePlot Utility

Model includes 1 or 2 slabs (i.e., base PCC and overlay)

Multiple Base Layers

Not Visible to the User During Design

Subgrade ("Infinite" Elements)

Tire Patch Loads

Slip Interface

Crack

Dense Liquid Foundation
FEM Model Approach

Cumulative Damage Factor (CDF)

- Difference in Gear Location
- Damage from Airplane A
- Damage from Airplane B

Cumulative Damage Factor (CDF)

- Total Damage
- Damage from Airplane A
- Damage from Airplane B

FAARFIELD – CDF Graphical Display
### Cumulative Damage Factor (CDF) for Some Aircraft

<table>
<thead>
<tr>
<th>Aircraft Name</th>
<th>Gross Weight</th>
<th>Annual Departures</th>
<th>CDF Contribution</th>
<th>CDF Max For Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sngl Whl-30</td>
<td>30,000</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Dual Whl-30</td>
<td>30,000</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Dual Whl-45</td>
<td>45,000</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>RegionalJet-200</td>
<td>47,450</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>RegionalJet-700</td>
<td>72,500</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Dual Whl-100</td>
<td>100,000</td>
<td>1,200</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DC-9-51</td>
<td>122,000</td>
<td>1,200</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>MD-83</td>
<td>161,000</td>
<td>1,200</td>
<td>0.39</td>
<td>0.39</td>
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<tr>
<td>B-737-400</td>
<td>150,500</td>
<td>1,200</td>
<td>0.09</td>
<td>0.09</td>
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<tr>
<td>B-727</td>
<td>172,000</td>
<td>1,200</td>
<td>0.23</td>
<td>0.24</td>
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<tr>
<td>B-757</td>
<td>250,000</td>
<td>1,200</td>
<td>0.02</td>
<td>0.03</td>
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<tr>
<td>A300-B2</td>
<td>304,000</td>
<td>1,200</td>
<td>0.01</td>
<td>0.16</td>
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<tr>
<td>B-767-200</td>
<td>335,000</td>
<td>1,200</td>
<td>0.02</td>
<td>0.15</td>
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<tr>
<td>A330</td>
<td>469,000</td>
<td>100</td>
<td>0.01</td>
<td>0.23</td>
</tr>
<tr>
<td>B-747-400</td>
<td>873,000</td>
<td>100</td>
<td>0.23</td>
<td>0.28</td>
</tr>
<tr>
<td>B-777-200</td>
<td>537,000</td>
<td>500</td>
<td>0.00</td>
<td>0.13</td>
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</tbody>
</table>
EFFECT OF GEAR POSITION & CRITICAL STRESS LOCATION

Rigid pavement thickness is designed based on critical tensile bending stress at the bottom of the slab. Top-Down cracking may occur under certain combined Loading and pavement geometry configuration.

(Full scale test - NAPTF and Airbus PEP)

Guo (2006) reported that tensile stress developed on slab bottom were related primarily to the wheel load, while the tensile stresses on the slab top were related primarily to the gear load at both longitudinal and transverse joint location.
EFFECT OF GEAR POSITION & CRITICAL STRESS LOCATION

2D Simulation on 9 slab (University of Urbana-Champaign)

- Four main landing gear (B-777, A-380, MD-11, & B747)
- Five individual aircraft gear geometry-Dual -B737
  - Dual Tandems- B747, B757, B767
  - Triple Dual Tandems-B-777

1. Individual Gear Analysis: (with assumption of no initial curling stresses)
2. Main landing Gear Analysis (two load transfer efficiencies (0 and 85%) were assumed across the joint)
EFFECT OF GEAR POSITION & CRITICAL STRESS LOCATION

1. Individual Gear Analysis: (with assumption of no initial curling stresses)
   
   - Due to small wheel spacing, B-737 produced greatest tensile stress at the bottom of the slab in y direction.
   
   - The largest Tensile stress at the top of the slab is came from TDT gear (B-777) in x-direction.
   
   - Max. tensile stress at top was similar in both direction for each gear type.
   
   - Gear load affected the max tensile stress at the top of the slab while wheel affected the max tensile stresses at the bottom of the slab.
   
   - Top-down cracking depends on top to bottom tensile stress ratio.
   
   - B-777 produced the highest tensile stress ratio.
EFFECT OF GEAR POSITION & CRITICAL STRESS LOCATION

2. Main landing Gear Analysis (two load transfer efficiencies (0 and 85%) were assumed across the joint)

- As the load transfer efficiency at the joints decreased for all aircraft, the max. tensile stresses at the top and bottom increased.

- The main landing gear of A-380 resulted in the highest top tensile stress.

- Max tensile stress on the top of the slab was in x-direction, which indicates that longitudinal cracking would be the most likely failure mode.

- MD-11 and A-380 have significantly higher tensile stresses at the bottom of the slab in y-direction compared to the tensile stress in x-direction, which would first lead to bottom-up transverse cracking.

- Due to large spacing between the main landing gear in B-777, produced lower top tensile stress in the main landing gear.
Tensile stress at the bottom of the slab are more critical.

The main landing gear of A-380 resulted in the largest top tensile stress.

The ratio of top to bottom of the slab tensile stress were significantly higher for full gear analysis relative to the individual gear analysis.

The critical top tensile stress occurred at the transverse joint would promote propagation of longitudinal cracks.
TOUCHDOWN IMPACT AND STRESSES

- During the touch down operation less than 50% of the weight of aircraft impacts on pavement.
- Aircrafts are lighter due to burning of fuel in the flight.
- A partial weight is taken by the flaps (opening of flaps during touchdown)
- Flaps changes horizontal energy to vertical energy which allow to decrease the sink rate prior to touchdown.
- The more flaps available and used, the slower the speed, the slower the touchdown and shorter the rollout.
Runway pavements are designed for static load.

The impact of landing is only about 38% of the takeoff static load.
Flap Effects

- Increase lift
  Increase drag
  More abrupt stall
  Lower stall speed

- Decrease climb rates
  Change pitch attitude
  Increase approach angle
  Decrease distance to lift-off
  Shorten Takeoff and Landing distance
## 747-8 vs. 747-400 Comparison

<table>
<thead>
<tr>
<th></th>
<th>747-8 (ft/m)</th>
<th>747-400 (ft/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span</td>
<td>224.4/68.4</td>
<td>213.0/64.9</td>
</tr>
<tr>
<td>Length</td>
<td>250.2/76.3</td>
<td>231.8/70.7</td>
</tr>
<tr>
<td>Height</td>
<td>64.2/19.6</td>
<td>64.0/19.5</td>
</tr>
</tbody>
</table>

- **747-8** is 0.2 ft (0.1 m) higher.
- **747-8** is 5.7 ft (1.8 m) wider each side.
- **747-8** is 18.4 ft (5.6 m) longer.
747-8 Freighter - General Arrangement

FAA Airport Design Group 6 – ARFF Index E
ICAO Aerodrome Reference Code F – RFFS Category 10
CDF Comparison for Group IV, V, and VI Aircraft

CDF Contribution for Various Aircraft (Group IV, V, and VI) for Different Pavement Section

- CDF Contribution for Sect.1 (Total=1.0)
- CDF Contribution for Sect.2 (Total=1.0)
- CDF Contribution for Sect.3 (Total=1.0)

PCC Layer, E=4,000,000 psi
Cement Flyash Crushed Concrete Base, E=500,000 psi
Cement Flyash Stabilized Sub-Base, E=40,000 psi

Total Number of Annual Departure = 1200 for each aircraft
<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Thickness in</th>
<th>Modulus psi</th>
<th>Poisson's Ratio</th>
<th>Strength R, psi</th>
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<tbody>
<tr>
<td>1</td>
<td>PCC Surface</td>
<td>19.00</td>
<td>4,000,000</td>
<td>0.15</td>
<td>700</td>
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<td>2</td>
<td>Undefined</td>
<td>16.00</td>
<td>500,000</td>
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<td>3</td>
<td>Undefined</td>
<td>8.00</td>
<td>40,000</td>
<td>0.35</td>
<td>0</td>
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<tr>
<td>4</td>
<td>Subgrade</td>
<td>0.00</td>
<td>4,000</td>
<td>0.40</td>
<td>0</td>
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</tbody>
</table>

**Total thickness to the top of the sub-grade = 43.26 in**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Gross Wt. lbs</th>
<th>Annual Departures</th>
<th>% Annual Growth</th>
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<tr>
<td>1</td>
<td>DC8-43</td>
<td>318,000</td>
<td>227</td>
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<td>2</td>
<td>DC9-32</td>
<td>109,000</td>
<td>69</td>
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<td>3</td>
<td>DC9-51</td>
<td>122,000</td>
<td>100,000</td>
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<td>4</td>
<td>DC9-51</td>
<td>122,000</td>
<td>36,511</td>
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<td>5</td>
<td>DC10-30/40</td>
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<td>2,522</td>
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<td>6</td>
<td>DC10-30/40 Belly</td>
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<td>7</td>
<td>Adv. B727-200C Basic</td>
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<td>14,781</td>
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<td>8</td>
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<td>82,956</td>
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<td>B737-800</td>
<td>174,700</td>
<td>77,036</td>
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<td>10</td>
<td>B747-400B Combi</td>
<td>877,000</td>
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<tr>
<td>11</td>
<td>B747-200B Combi Mixed</td>
<td>836,000</td>
<td>929</td>
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<tr>
<td>12</td>
<td>B757-200</td>
<td>256,000</td>
<td>478</td>
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<tr>
<td>13</td>
<td>B777-200LR</td>
<td>768,000</td>
<td>10,258</td>
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<td>14</td>
<td>A320-100</td>
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<td>568,563</td>
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</table>
Stress Computation for TW-WB, output from FAARFIELD
FAARFIELD: Stress/Strain Analysis at the Bottom of the Flexible Pavement

Stress Computation for TW-WB Shoulder, output from FAARFIELD
Section-3

Pavement Evaluation & Management System

- Pavement Strength Evaluation and Rating process
  - PCI Rating
  - NDT
  - ACN-PCN Evaluation
- Life Cycle Modeling
- Decision Matrix
- Pavement Management Software
- Evaluation of Concrete and Metal Structure through Soils Resistivity Analysis
To Evaluate the current Pavement condition
Detail Plan for repair (what/When/How..)
Cost Benefit Analysis
Justification
What happens if not repair at this point?
All these are answered
Pavement Evaluation & Rating Process

Pavement Condition Index (PCI)
Structural Condition Index (SCI)

NDT And Back Calculation for Strength Evaluation, Validate w/Field Testing

Traffic Analysis- AIRPAVE

ACN-PCN Evaluation
Pavement Thickness

Minimum Service Level
Runways 75
Taxiways 70
Aprons 65

COMFAA
BACKFAA
FAARFIELD
# Pavement Evaluation: Distresses

**AC 150/5380-6**  
**ASTM D 5340-10**  
**Distress Severity, Qty. & Type**

<table>
<thead>
<tr>
<th>Flexible pavement</th>
<th>Rigid pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator</td>
<td>Blow Up</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Corner Break</td>
</tr>
<tr>
<td>Block Cracking</td>
<td>LTD Cracking</td>
</tr>
<tr>
<td>Corrugation</td>
<td>D- Cracking</td>
</tr>
<tr>
<td>Depression</td>
<td>Joint Seal Damage</td>
</tr>
<tr>
<td>Jet Blast Erosion</td>
<td>Large Patch</td>
</tr>
<tr>
<td>Long,.&amp; Trans. Cracking</td>
<td>Pumping</td>
</tr>
<tr>
<td>Small Patch</td>
<td>Pop Outs</td>
</tr>
<tr>
<td>Oil Spill</td>
<td>Faulting</td>
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<tr>
<td>Joint Refl. Cracking</td>
<td>Shattered Slab</td>
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<tr>
<td>Polished Agg.</td>
<td>Shrinkage</td>
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<tr>
<td>Raveling/Weathering</td>
<td>Joint Spalling</td>
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<tr>
<td>Rutting</td>
<td>Corner Spalling</td>
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<tr>
<td>Shoving From PCC</td>
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</tr>
<tr>
<td>Slippage</td>
<td></td>
</tr>
<tr>
<td>Swelling</td>
<td></td>
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</table>
Strength Evaluation: NDT Modulus (Back-calculation)

Top layer

Base layer

Sub-grade
Determination of ACN-PCN Using COMFAA 3.0

COMFAA 3.0 Screen Shot and Equivalent Section Determination
ACN-PCN Evaluation Using COMFAA 3.0

Example Output from COMFAA 3.0 TW SA/SB

PCN Reporting Format:
PCN Number/Pavement Type/Tire Pressure/Method of Calculation (Technical/Using Airplane)
FACTORS AFFECTING ACN-PCN EVALUATION

- Sub-grade Modulus
- Pavement Thickness
- Traffic loading/type and Gear
- Engineering Judgment (Personal decisions)

Example: TW SA/SB Section #2108 Evaluation with DMJM Traffic Projection
Life Cycle Cost Analysis

LCCA Model
PAVEAIR: Web Based Project Management Tool

Pave Air Beta Version
Rehabilitation Alternatives and Decision Making Criteria

### Matrix Comparison of PCC Pavement Rehabilitation Alternatives

<table>
<thead>
<tr>
<th>Pavement Rehabilitation Alternative</th>
<th>Airway Operation Impact</th>
<th>Construction</th>
<th>Performance</th>
<th>Cost</th>
<th>Total Score</th>
<th>Weighted Score</th>
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<tr>
<td></td>
<td>Runway Closure</td>
<td>Tenant Impact</td>
<td>Sustainability</td>
<td>Time</td>
<td>Smoothness</td>
<td>Initial Construction</td>
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<tr>
<td>Weighted Factor</td>
<td>15</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>25</td>
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<tr>
<td>Total Reconstruction</td>
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<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
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<td>Partial Reconstruction</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Un-bonded PCC Overlay</td>
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<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Bonded PCC Overlay</td>
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<td>4</td>
<td>5</td>
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*Rating Scale: 5- Excellent, 4- Very Good, 3- Good, 2- Fair, 1- Poor, 0- Very Poor*

Rehabilitation of Taxiways WA-WB and New West Vault
<table>
<thead>
<tr>
<th>Rating Scale</th>
<th>5 - Excellent</th>
<th>4 - Very Good</th>
<th>3 - Good</th>
<th>2 - Fair</th>
<th>1 - Poor</th>
<th>0 - Very Poor</th>
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<tbody>
<tr>
<td></td>
<td>CONSTRUCTION</td>
<td>DESIGN</td>
<td>PERFORMANCE</td>
<td>COSTS</td>
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<tr>
<td></td>
<td>Constructability</td>
<td>Contractor Familiarity</td>
<td>Feasibility</td>
<td>Schedule Risk</td>
<td>Impacts to Airfield Electrical Infrastructure &amp; ILS</td>
<td>Grade Compatibility</td>
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<td>Options</td>
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<td></td>
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<td>PC Concrete Jointed Overlay (mill 3&quot; of existing AC)</td>
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<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
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<tr>
<td>2</td>
<td>PC Concrete Jointed Overlay (mill existing AC to LCF base)</td>
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<td>5</td>
<td>5</td>
<td>3</td>
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<td>3</td>
<td>Continuously Reinforced Concrete Overlay (Mill 3&quot; of Existing AC)</td>
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<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
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</tbody>
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Section-4

Soils Resistivity and Corrosion Potential of Native Sub-grade Soils
Concrete and metal structures are deteriorated at a faster rate with soils corrosion activity. Soils Corrosivity is measured by Soils Resistivity.
Soils Resistivity Testing

Method of Soils Resistivity Testing

Field Testing

Lab Testing

Schematic Diagram For Field Testing Setup
Factors:

- Soils PH
- Mineral Content (Chloride And Sulfate Ions)
- Soils Types
- Moisture Content
- Temperature and Environment
General Trend of Soils pH To Rate of Corrosion

High Moisture Content (Shallow Water Table)
High Temperature
Acidic Environment
Highly Plasticity Soils

These conditions may accelerate corrosion activity
Sulfate and Chloride Ion Concentration

<table>
<thead>
<tr>
<th>Sulfate Exposure</th>
<th>Water Soluble Sulphates (So4) (in % by wt.)</th>
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</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>0.00 ≤ SO4 &lt; 0.10</td>
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<tr>
<td>Moderate</td>
<td>0.10 ≤ SO4 &lt; 2.0</td>
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<tr>
<td>Severe</td>
<td>0.20 ≤ SO4 &lt; 2.0</td>
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<tr>
<td>Very Severe</td>
<td>SO4 &gt; 2.0</td>
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</table>

As per AASHTO specification, the maximum acceptable levels for chloride is 100 PPM and for sulfates is 200 PPM for minimum resistivity level of 3000 Ohm-cm.
Soils Resistivity Test Results

FIELD Soils Resistivity Testing IAH

LAB Soils Resistivity Testing-IAH

Soil Corrosion Rating

<table>
<thead>
<tr>
<th>Resistivity (in Ohm-cm)</th>
<th>Corrosion State</th>
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<tbody>
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<td>Higher than 20,000</td>
<td>Essentially non corrosive</td>
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<tr>
<td>10,000-20,000</td>
<td>Mild corrosive</td>
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<tr>
<td><strong>5000-10000</strong></td>
<td>Moderately corrosive</td>
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<tr>
<td>3000-5000</td>
<td>Corrosive</td>
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<tr>
<td>1000-3000</td>
<td>Highly corrosive</td>
</tr>
<tr>
<td>Less than 1000</td>
<td>Extremely corrosive</td>
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</table>
Research on Soils Resistivity Testing is Going on
References:


• Pokhrel, D.R. (2011). “Current Status and Issues with the Geotechnical Engineering At Houston Airport System”, PDC Project Status Briefings, Department of Aviation, Houston Airport Systems.

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